(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
10 April 2003 (10.04.2003)

PCT

(10) International Publication Number
WO 03/029013 A1

(51) International Patent Classification[7]: B41J 33/34, G11B 15/43

(21) International Application Number: PCT/GB02/04405

(22) International Filing Date: 30 September 2002 (30.09.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0123303.0 28 September 2001 (28.09.2001) GB

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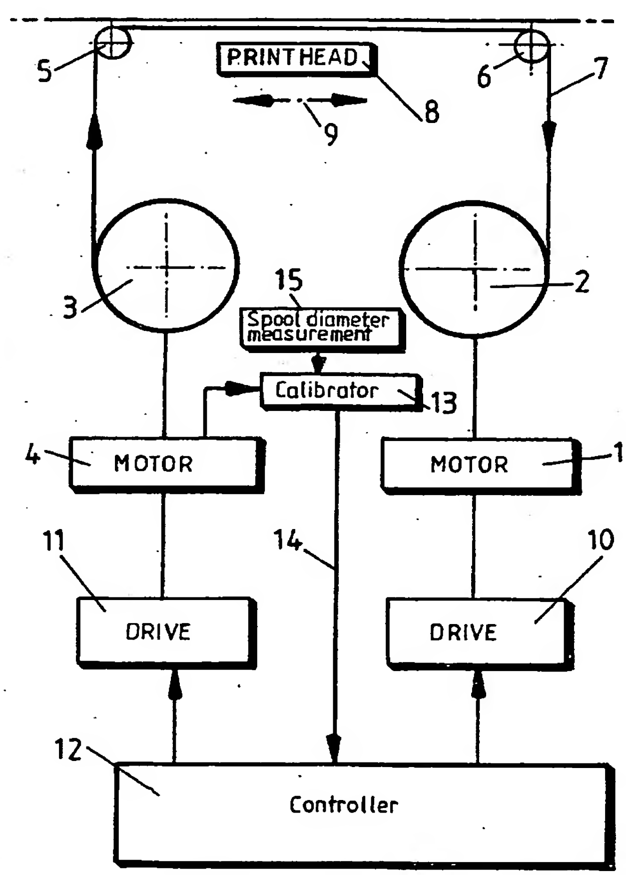
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),

[Continued on next page]

(54) Title: TAPE DRIVE



(57) Abstract: A tape drive comprising first and second motors, first and second tape spool supports on which respective first and second spools of tape may be mounted, each spool being driveable by a respective motor, and a controller for controlling the motors such that the tape may be transported from the second spool to the first spool. The first motor is a stepper motor. The controller is operative to energise the first stepper motor to draw the tape in a tape transport direction on to the first spool and to control the second motor such that the second motor resists rotation of the second spool in the direction of tape transport. The diameter of the spool supported by the second spool support is measured, and control of the second motor is varied as a function of the determined diameter of the spool supported by the second spool support, the function being such that tension in the tape is maintained within predetermined limits. The second motor may also be a stepper motor, but may be a DC motor. Tape spool diameter may be measured, for example optically, or calculated, for example by reference to a measurement of tape transport distance and the corresponding motor rotation.

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European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

TAPE DRIVE

The present invention relates to a tape drive, for example a tape drive which may form part of a transfer printer which makes use of tape-supported inks, or a label applicator which applies tape-supported labels to a substrate.

In transfer printers, a tape, which is normally referred to as a printer tape and carries ink on one side, is presented between a printhead and a substrate with the ink-carrying side facing the substrate. The printhead is operative to transfer ink from the tape on to the target substrate which may be for example paper or a flexible film. Such printers are used in many applications, notably for printing information on cartons and the like. In particular, transfer label printers and thermal transfer coders print directly onto substrates such as packaging materials manufactured from flexible film or card.

Tape is normally delivered to the end user in the form of a spool of tape wound onto a core. The end user pushes the core onto a tape spool support, pulls the free end of the tape to release a length of the tape, and then engages the free end of the tape with a further spool support. Generally the spool supports are mounted on a cassette which can be readily mounted on a printing machine. The printing machine includes a transport means for driving the two spools in a tape transport direction so as to unwind tape from one spool (deemed the supply spool) and wind tape onto the other spool (deemed the take-up spool). The printing apparatus transports tape between the two spools along a predetermined path past the printing head. In some applications tape transport is in only one direction, but in other applications tape may be transported in both directions alternately.

Known printers of the above type rely upon a wide range of different approaches to the problem of how to drive the tape spools. Some rely upon stepper motors, others on DC motors, to directly or indirectly drive the spools. Generally, in commercially available printers, only the take-up spool is driven in the tape

transport direction and some form of "slipping clutch" arrangement is connected to the supply spool to provide a resistive "drag" force so as to ensure the tape is maintained in tension during the printing and tape winding processes and to prevent tape over-run when it is desired to bring the tape to rest. It will be appreciated that maintaining adequate tension is an essential requirement for the proper functioning of the printer.

As a roll of tape is gradually used by the printer, the initial outside diameter of the supply spool decreases and the initial outside diameter of the take-up spool increases. In slipping clutch arrangements which offer an essentially constant resistive torque, the tape tension will vary in proportion to the diameter of the supply spool. Given that it is desirable to use large supply spools so as to minimise the number of times that the tape has to be replenished, this is a serious problem.

It is generally the case that a slipping clutch is very difficult to set up. This is because the initial large diameter and associated large inertia of the supply spool means that a high drag level is required in order to avoid over-run of the supply spool during operation. As the supply spool reduces in size, the tension of the tape increases, and the previously necessary high drag level results in excessive tape tension. This can result in over tensioning, causing tape breakage, or stalling of the motor driving the tape up spool, particularly if the tape is driven at high speed or is accelerated and decelerated at high rates. Thus the problems associated with slipping clutch arrangements limit the performance of printers by limiting the maximum acceptable rate of acceleration, rate of deceleration and speed of the tape transport system.

In modern thermal transfer printers, limitations imposed by the tape transport system significantly compromise performance given that other components of the printers are capable at operating at very high speeds. For example, in "intermittent" transfer printers the printer tape is stationary during a printing operation (during which the printhead is traversed relative to the tape and the

substrate to be printed) and must thereafter be rapidly advanced and then brought to a standstill again in time for the next printing operation. The number of printing operations that can be completed per unit time is dependent upon the maximum rates of acceleration and deceleration which the tape supply system can deliver. In "continuous" printers, the printhead is stationary and the substrate to be printed is transported continuously past the printhead. The speed of the tape must track that of the substrate whilst printing is occurring during each printing cycle, but generally the tape is stopped or driven in the opposite directions between printing cycles. In addition, the speed of the substrate (which is often determined by the speed of associated manufacturing equipment) can change rapidly. High rates of tape acceleration and deceleration are therefore required.

Further details of the manner of operation of intermittent and continuous printers can be obtained from British Patent No. 2369326.

The high performance demands of modern thermal printers can only be met if tape tension can be accurately controlled. Tape tension can only be controlled accurately if the tape drive system is dynamically modified throughout the transport of the roll of tape from the supply spool to the take-up spool. Proposals have been made for adjusting a tape drive system during tape transfer to take account of the changing outside diameters of the supply and take-up spools. For example, proposals have been made to apply a drag force to the supply spool which reduces as the diameter of the supply spool decreases. The diameter of the supply spool is not directly monitored however, but rather is calculated on the basis that the sum of the cross-sectional areas of the two spools is known and is approximately constant throughout the tape transfer process (hereinafter the "conservation of area principle"). This assumption is only valid however if for all tapes the sum of the cross-sectional areas is always the same, and all the tape is supported by one particular spool at the outset of the tape transfer process. In the real world such conveniently predictable circumstances often do not arise.

Circumstances cannot be reliably predicted for various reasons. It is not always possible to start with all the tape on one spool, and with a known spool diameter. For example, different spools of tape may have different diameters because they have different lengths of tape on them or tape of different thickness. Furthermore it is often necessary to fit a tape cassette to a printer that carries a tape partially wound on one spool and partially wound on the other. Such a situation can arise for example when a cassette, in which the tape was originally all on one spool, is removed from the printer after partial use, to enable the printer to use a different tape (for example a tape with ink of a different colour). In the case of tape breakage some of a tape may be discarded so as to make it possible to use the remainder. This results in a length and volume of tape which is entirely unpredictable. A system which can only stabilise tape tension when used with a cassette that when first mounted on the printer has all of the tape supported on one tape spool, the tape being of known length and thickness, does not therefore fully address the problem.

Further problems arise with tape systems which rely upon the "conservation of area" principle to predict the change in tape spool diameter which occurs as tape is transported between the supply and take-up spools if the tape characteristics change between the two spools. For example, labelling machines are known in which a tape carrying a series of adhesive labels is initially supported on a supply spool and transported to a take-up spool. The labels are peeled off the tape between the supply and take-up spools such that the diameter of the supply spools when initially installed is greater than the diameter of the take-up spool after all of the tape (minus labels) has been transferred to the take-up spool.

Examples of tape drives exemplifying the prior art discussed above are described below.

US 4,294,552 describes a tape drive in which two stepper motors are used, a first motor driving a take-up spool in a conventional manner, and the second motor

being configured such that its motor windings provide drag. A substantially constant drag current is passed through the windings of the second motor using cross-coupled connections from the first stepper motor. This tape drive suffers from the significant disadvantage that the constant drag current will not result in a constant tension being applied to the tape.

EP 0 546 303 discloses a tape drive comprising two stepper motors each coupled to a respective tape spool. The tape transport direction is reversible and the primary objective is achievement of uniform tape velocity, with tape tension control a secondary consideration. The motor coupled to the supply spool operates in regenerative mode, thus generating drag. The motor coupled to the take-up spool is driven by pulse width modulated sine waves so as to generate constant torque. In order to provide uniform tape velocity the angular velocity of the take-up motor is controlled by reference to a look-up table. Tape tension is controlled by connecting the windings of the motor coupled to the supply spool to a variable load. The drag provided by the supply spool motor is varied, but there are only four possible drag magnitudes. The relative radii of the tape spools is calculated from the angular velocity of the supply motor. The angular velocity of the take-up motor is then controlled so as to maintain a given linear tape speed. Tape tension is not stabilised by taking account of supply spool diameter variations.

US 5,490,638 describes a tape drive in which two stepper motors are provided, one being coupled to each of the tape spools. The supply spool motor drags because its windings are connected to a resistive load. The amount of drag is controlled by controlling the level of the load current at a desired value. That load current can be set to one of a number of possible values by selecting one of a number of resistors that form part of a potentiometer that sets the current level. Again however the circuit is set up to maintain constant tape velocity and tape tension control is a secondary issue.

US 4,573,645 describes a tape drive in which the two tape spools are coupled to respective stepper motors. The stepper motor coupled to the supply spool acts as a generator and the loading of the generator is controlled by driving current through load resistors. The magnitude of the current driven through the load resistors is controlled to compensate for changes in spool diameters. However this compensation relies upon knowledge of the initial diameter of the supply spool which is not generally predictable for the reasons discussed above and furthermore assumes that the sum of the cross-sectional areas of the two spools of tape remains constant. In the real world it is not acceptable to have to rely on the assumption that the initial diameter of a supply spool is predetermined and the cross sectional area of the supply and take-up spools is constant.

It is an object of the present invention to obviate or mitigate the problems outlined above.

According to the present invention, there is provided a tape drive comprising first and second motors, first and second tape spool supports on which respective first and second spools of tape may be mounted, each spool being driveable by a respective motor, and a controller for controlling the motors such that the tape may be transported from the second spool to the first spool, wherein the first motor is a stepper motor, and the controller is operative to energise the first stepper motor to draw the tape in a tape transport direction on to the first spool and to control the second motor such that the second motor resists rotation of the second spool in the direction of tape transport, means being provided to determine the diameter of the spool supported by the second spool support, and to vary control of the second motor as a function of the determined diameter of the spool supported by the second spool support, the function being such that tension in the tape is maintained within predetermined limits.

The diameter determining means may comprise means for measuring the diameter of the second spool, for example an optical arrangement which may comprise at least one optical emitter positioned such that a shadow is cast by at

least the second spool, at least one optical detector adapted to detect the position of an edge of the shadow, and means to determine the diameter of the second spool from the detected position of the edge of the shadow.

In one arrangement, the emitter or the detector may be mounted on a translatable carriage, such that components of the optical arrangement are displaced through a position corresponding to the shadow edge. For example, a detector may be mounted on the translatable carriage with two emitters positioned such that the first and second spools cast shadows edges of which are located on a track along which the detector is displaced. Alternatively, an emitter may be mounted on the translatable carriage with two detectors positioned such that the edges of shadows cast by the first and second spools are displaced past the detectors as the emitter is displaced on the carriage. As a further alternative, an emitter and a detector may be mounted on the carriage, with a mirror positioned to reflect light from the emitter to the detector, at least the second spool being located between the carriage and mirror such that the second spool obstructs reflection of light from the emitter to the detector to an extent dependent upon the diameter of the second spool.

In an alternative arrangement which does not require a translatable carriage, the detector comprises an elongate array of detectors positioned such that the shadow edge moves along the length of the array as the diameter of the second spool changes.

The tape drive may be part of a printer which operates cyclically with each cycle including a printing operation, and the diameter of the second spool may be measured at intervals between successive printing cycles.

As an alternative to measuring the diameter of the second spool, the diameter of the second spool may be calculated. For example, means may be provided for monitoring tape transport and rotation of at least one motor, and means may be

provided for calculating the diameter of the second spool from the measured tape transport and motor rotation.

Rather than relying on only either direct measurement or calculation of spool diameter, the current diameter of the second spool may be estimated from a previously determined spool diameter and subsequent operation of the tape drive. For example, estimating means may be provided which is operative to estimate the current diameter on the assumption that the total cross-sectional area of the supply and take-up spools is a constant.

Preferably, the first and second motor are stepper motors, the second motor is connected to a load, and means are provided to control current drawn by the load as a function of the determined diameter. A feedback circuit may be connected to the load, the feedback circuit being configured to maintain the current drawn by the load at a required level determined by the controller. The circuit may be arranged periodically to connect the load to the windings of the second stepper motor in accordance with a pulse width modulated signal, adjustment of the pulse width modulated signal providing adjustment of the average load.

The feedback circuit may comprise a first filter which provides a DC value indicative of the current passing through the load, a second filter which provides a DC value indicative of the pulse width modulated signal, and means for comparing the DC values to provide a feedback signal. The feedback circuit may further comprise a sawtooth function generator arranged to generate a sawtooth signal, and means for comparing the feedback signal and the sawtooth signal to provide a sawtooth modulated feedback signal which controls the connection means. The load may be connected to the windings by a transistor which is turned on and off by the pulse width modulated signal. Diodes may be connected between windings of the second stepper motor and the load to prevent flow of current from the load to the windings, and the controller may be provided with enable means configured to ensure that current is passed from the windings of

the second stepper motor to the load only when drive current is not being supplied to the second stepper motor.

Each element of the tape drive which is provided for the second stepper motor may be in addition provided for the first stepper motor and vice versa, such that tape may be transported from the first reel to the second reel, that is the tape may be driven in both directions between the spools. Although preferably the second motor is a stepper motor, the second motor could be a DC motor, in which case drive current to the DC motor is controlled as a function of the determined diameter, for example such that the drive current is directly proportional to the determined diameter.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic illustration of components of a tape drive in accordance with the present invention;

Figure 2 illustrates an embodiment of the present invention in which a calibrator is responsive to inputs received from a tape spool drive motor and a tape spool diameter measurement device;

Figure 3 is a schematic representation of a tape spool diameter measuring device suitable for use in the embodiment of Figure 2;

Figure 4 is a schematic illustration of dimensions of tape spools which may be used in the calculation of an estimate of changes in tape spool diameter as a result of tape transport between spools;

Figure 5 is a schematic illustration of an embodiment of the present invention in which a calibrator receives inputs from a tape transport measurement device and a supply spool drive motor;

Figure 6 is a schematic illustration of an embodiment of the invention in which a take-up spool is driven by a stepper motor, a supply spool is driven by a DC motor, and a calibrator is responsive to inputs from optical sensors such as those illustrated in Figure 3 and the stepper motor driving the take-up spool;

Figure 7 illustrates a further embodiment of the present invention in which both take-up and supply spools are driven by stepper motors and a calibrator is responsive to inputs from both the stepper motors and a tape transport measurement device in the form of a roller which contacts the tape;

Figure 8 is a more detailed illustration of components illustrated in Figure 7;

Figure 9 illustrates waveforms generated by windings of a stepper motor in the embodiments of the invention illustrated in Figure 8; and

Figure 10 is an illustration of a further embodiment of the invention which is of the same general type as that shown in Figure 8 but has a modified stepper drive control circuit.

Referring to Figure 1, this illustrates in a generalised form the components of a tape drive in accordance with the present invention. A first drive motor 1 which is a stepper motor is coupled to a tape spool support (not shown) on which a first tape spool 2 is supported. The tape spool 2 acts as a take-up spool, drawing tape from a second tape supply spool 3 which is coupled to a second drive motor 4. Depending on the embodiment of the invention, the motor 4 could be either a DC motor or a stepper motor. The tape follows a path from the supply spool 3 to the take-up spool 2 around a pair of idler rollers 5 and 6. The length of tape extending between the rollers 5 and 6 extends parallel to a path indicated by line 7 along which in use a substrate which is to be printed is transported. A printhead 8 is positioned so that the tape is located between it and the substrate path 7 so as to enable the transfer of ink from the tape to a substrate on that path

7. Depending on the type of printer, the printhead may be stationary relative to the idler rollers 5 and 6 or may be transportable in a direction parallel to the idler rollers 5 and 6 as indicated by arrow 9.

The motor 1 is driven by a drive 10 and the motor 4 is driven by a drive 11. The two motors drives are controlled by a controller 12.

All of the components described so far with regard to Figure 1 can be found in prior art printers. In accordance with the present invention however the controller is also connected to a calibrator 13 which provides an input to the controller representative of the outside diameter of at least the supply spool 3. The motor 1 is driven at a speed appropriate to the particular application in which the printer is deployed. The manner in which this speed is determined is not of direct relevance to the present invention. The motor 4 however is controlled by the drive 11 so as to resist rotation of the supply spool 3. This results in the generation of a torque which operates on the supply spool 3 in a direction opposite to the direction of tape transport. This torque and the diameter of the supply spool 3 determines the tension in the tape extending between the idler rollers 5 and 6. It is the purpose of the present invention to maintain that tension within predetermined limits and therefore it is necessary to know the diameter of the supply spool 3 if the torque applied to that spool by the motor 4 is to be appropriately controlled. Hence the calibrator 13 is provided to deliver to the controller an input 14 representative of that diameter.

The calibrator 13 may derive the necessary supply spool diameter measurement in any appropriate manner. One general arrangement which relies upon an initial direct measurement of spool diameter and thereafter calculation of changing spool diameter over time is illustrated in Figure 2. The same reference numerals are used in Figures 1 and 2 for like components.

In the arrangement illustrated in Figure 2, the calibrator receives an output from a spool diameter measurement device 15 which delivers to the calibrator 13

a signal representative of the diameter of the supply spool 3. The calibrator 13 also receives an input from the supply spool motor 4 representative of angular rotation of the motor 4, that input being derived for example from a shaft encoder or (if the motor 4 is a stepper motor) a motor step counting device. An initial measurement of the outside diameter of the spool 3 is made at least when the spools 2 and 3 are first coupled to the motors 1 and 4. Thereafter, given knowledge of the thickness of the tape supported on the spool and the number of revolutions of spool 3 (derived from knowledge of the number of revolutions of the motor 4), the changing diameter of the supply spool 3 can be calculated as described above.

Although in accordance with the present invention tape tension can be controlled purely on the basis of knowledge of the diameter of and torque applied to the supply spool 3, preferably the diameters of both the take-up and supply spools 2, 3 are measured and the calibrator receives an input from the supply spool motor 4 and the take-up spool motor 1 so as to enable appropriate control of the take-up spool speed as well as the torque applied to the supply spool. Figure 3 illustrates such an arrangement in which the diameters of both spools are measured and the rotation of both motors is monitored.

Figure 3 shows a direct connection between the motor 1 and the calibrator 13 to enable rotation of the take-up spool 2 by the motor 1 to be monitored. Such an arrangement is possible, but it will be appreciated that although rotation of the stepper motor 1 could be monitored directly from the motor itself it could also be monitored by monitoring the motor drive 10 or the controller 12. The motor 1 will step or not step in response to step pulses delivered by the drive 10. The drive 10 delivers step pulses in response to control signals from the controller 12. As a result rotation of the motor 1 is locked in synchronisation with the operation of both the drive 10 and the controller 12, and therefore motor rotation can be monitored indirectly by monitoring the operation of either the drive 10 or the controller 12.

Referring to Figure 3, once again the same reference numerals are used where appropriate. The spool diameter measuring apparatus illustrated in Figure 3 provides measurements of the diameters of both the supply spool 3 and the take-up spool 2. Two optical emitter devices 16 and 17 are located beneath the spools 2, 3 and are used in conjunction with a detector 18 mounted on a carriage 19, the carriage being displaceable in a direction indicated by line 20 so that in one extreme position the detector 18 is located at a position indicated by broken line 21 and at the other extreme the detector 18 is located at the position indicated by broken line 22. The carriage 19 could also serve to transport the printhead of the device in some embodiments of the invention. As the detector 18 is moved to the left in Figure 3 from the position indicated by line 22, initially only emitter 16 is energised. Initially the detector 18 is in the shadow of the spool 2, but as soon as the detector 18 crosses the plane indicated by line 23 an output signal will be generated by the detector 18. This is coupled by a flexible cable 24 to the calibrator 13. The detector 18 is then advanced further towards the position indicated by line 21 and its output disappears as the detector crosses the plane indicated by line 25. The carriage then continues until the detector 18 is at the position indicated by line 21. The carriage is then returned after the emitter 16 has been deenergised and the emitter 17 has been energised.

During the return travel of the carriage, the detector 18 is initially in the shadow cast by the spool 3 but will generate an output as soon as it reaches the plane indicated by the line 26. The carriage 19 continues to advance until that output disappears as the detector 18 crosses the plane indicated by the line 27. Thus the position at which the planes indicated by lines 23, 25, 26 and 27 intersects the path of the detector 18 can be determined.

The distance between the axes of rotation of the spools 2 and 3 is known and is indicated in Figure 3 as dimension A. The perpendicular distance between the track followed by the detector 18 and the plane in which the emitters 16 and 17 are located is also known (dimension B in Figure 3). The distance between the track followed by the detector 18 and the plane including the axes of the spools 2

and 3 is also known (dimension C in Figure 3). From these dimensions the diameters D1 and D2 of the take-up and supply spools 2 and 3 can be readily derived using simple trigonometry.

Two emitters 16 and 17 which are alternately energised are used to ensure that on each traverse of the detector 18 the detector always enters an area of shadow cast by at least one of the spools regardless of spool diameter.

It will be appreciated that the calculation of the spool diameters would be somewhat simpler if the planes indicated by lines 23, 25, 26 and 27 were perpendicular to the direction of displacement of the detector 18. This can be achieved by for example replacing the emitters 16 and 17 with a mirror extending parallel to the direction of displacement of the carriage 19 and arranging both a transmitter and a detector on the carriage 19, the transmitter and detector being spaced apart in a direction parallel to the tape spool axes. With such an arrangement the detector would detect light only when both it and the emitter are located on a plane perpendicular to the mirror which is not obstructed by a tape spool. Although such an arrangement is simpler in terms of the required calculation of tape spool diameters, it has disadvantages in that dust or a foreign particle settling on the mirror could be interpreted as the detector being in the shadow of one of the spools. In contrast, with the system as described with reference to Figure 3 contamination with dust or foreign particles could be more readily detected.

The spool diameter measurement device as described with reference to Figure 3 is dependent upon movement of the detector 18 which can conveniently be achieved by mounting the detector 18 on the carriage used to transport the printhead. In "intermittent" printers the printhead is displaced relative to the tape and substrate during each printing cycle. In "continuous" printers however in which both the substrate and ribbon are moved past a stationary printhead there is no need to provide a traversing carriage and therefore the spool diameter measurement system as described in Figure 3 can only be applied if an

otherwise unnecessary transport mechanism is provided to move the detector 18. It would however be possible to avoid the need for such a transport mechanism if, rather than relying upon a moving detector 18, a linear array of detectors was provided extending along the path traversed by the detector 18 in the arrangement as described in Figure 3. If one of any pair of adjacent detectors along the array was illuminated and the other was not, this would indicate that a shadow cast by the adjacent spool fell between those two detectors. Thus an approximation of the spool diameter could be derived, the accuracy of the approximation being a function of the spacing between adjacent detectors in the array.

With the arrangement of Figure 3 it may be possible to measure spool diameters at closely spaced intervals in time, for example each time or every few times the printhead carriage traverses relative to the spools. On the other hand this may not be convenient, particularly as during a printing cycle the distance traversed by the printhead may be much less than that required to ensure that the detector 18 cuts through the planes defining the boundaries between areas which are illuminated and areas which are in shadow. Similarly, if a linear array of detectors is used, only a finite number of diameter "range" measurements can be made, each "range" corresponding to the change in spool diameter required to move the illuminated/in shadow boundary from the location of one detector to the location of the next detector in the array. The instantaneous spool diameters may be determined with greater accuracy however by calculation based upon knowledge of the optically measured diameters and subsequent rotation of the spools.

Referring to Figure 4, the shaded areas A_S and A_T are the areas of the supply spool 3 and take-up spool 2 (see Figure 2) respectively, d is the inner diameter of the spools (i.e. when no tape is held on the spools) and D_S and D_T are the outer diameters of the spools at any given time. Assuming that the two spools are wound with roughly the same tension, then the total area of the spools will be approximately constant. Hence:

$A_S + A_T = \text{constant}$ (1)

$A_S = (D_S/2)^2 - (d/2)^2$ (2)

$A_T = (D_T/2)^2 - (d/2)^2$ (3)

Substituting from (2) and (3) into (1) gives:

$D_S^2 + D_T^2 = \text{constant} = D_{SC}^2 + D_{TC}^2$ (4)

Where D_{SC} and D_{TC} are previously measured supply and take-up spool diameters respectively.

The current diameter ratio R is defined by:

$R = D_T/D_S$

This may also be arranged as:

$D_S = D_T/R$

And also:

$D_T = RD_S$

Substituting in (4) gives:

$$D_T^2 + D_T^2/R^2 = D_{TC}^2 + D_{SC}^2 = R_C^2 D_{SC}^2 + D_{SC}^2 = D_{SC}^2 (R_C^2 + 1)$$

where R_C is the ratio of the previously measured take-up spool to supply spool diameters.

Therefore $D_T^2 (R^2 + 1) / R^2 = D_{SC}^2 (R_C^2 + 1)$ and

$D_T^2 = [R^2/(R^2+1)] [D_{SC}^2 (R_C^2+1)]$

Similarly:

$D_s^2 = [1/(R^2+1)] [D_{SC}^2 (R_C^2+1)]$

Thus given that the measured spool diameters ratio R_C, the measured supply spool diameter D_{SC}, and the current spool diameters ratio R are known, an estimate of the current diameter of either or both reels D_S or D_T can be derived. The thickness of the tape can be measured or is known from knowledge of the thickness of tapes provided by the tape supplier, and the number of rotations of

the supply spool is known on the basis of the output to the calibrator 13 from the motor 4. This makes it possible to determine the current reel diameter ratio (R).

Given accurate knowledge of the supply spool diameter and the ability to control the torque applied to the supply spool by the motor 4 the tension in the tape can be controlled given that tape tension, motor torque and supply spool radius are related by the following equation:

(Torque) = (Tension) (Radius)

Thus, referring again to Figure 2, the calibrator 13 receives an input representative of spool diameter measurement from the measurement device 15 and an input representative of rotation of the motor 4 and delivers output 14 to the controller, the output 14 representing the instantaneous diameter of the supply spool 3. The controller 12 may incorporate a processor with a pre-loaded value representing a target tension. That target tension will determine the input to the motor drive 11 from the controller 12, the motor drive 11 being controlled so as to drive the motor 4 in a manner such that as the supply spool radius decreases the motor torque also decreases so as to maintain the tape tension substantially constant.

In the embodiment of the invention illustrated in Figure 2, the spool diameter measurement is achieved using an optical system as illustrated in Figure 3. Alternative arrangements are possible however which do not rely upon direct measurement of spool diameter but rather calculate the spool diameter on the basis of signals representing tape transport and spool rotation. Such an arrangement is schematically illustrated in Figure 5, again the same reference numerals being used as in Figure 1 where appropriate.

Referring to Figure 5, a tape transport measurement device 28 is positioned at some point adjacent the tape transport path so as to be able to generate an output 29 from which the length of tape dispensed in a given period can be

derived. The output 29 is applied to the calibrator 13 which also receives an output 30 from the motor 4, the output 30 being representative of rotations of the supply spool 3. The calibrator 13 calculates from the length of tape transported past the device 28 in a given period and the number of revolutions of the spool 3 in that same period the circumference of the spool 3 on the basis that:

(Circumference) (number of revolutions) = (tape transport length)

The radius of the spool 3 can be calculated from the circumference and hence all the information required to control tape tension is available.

Referring now to Figure 6, this illustrates an embodiment of the invention intended to draw tape only in one direction, the take-up spool 2 being driven by a stepper motor and the supply spool 3 being driven by a DC motor. Where appropriate once again the same reference numerals are used as were used in Figure 1. The calibrator 13 is shown coupled to an optical sensing device 31 which could be for example of the type illustrated in Figure 3 and which delivers to the calibrator information representing the diameters of both the supply spool 3 and the take-up spool 2 during an initial calibration phase before the tape is transported for printing purposes.

In use, the take-up spool 2 is driven to rotate in a clockwise direction (as viewed in Figure 6) by the stepper motor 1, thereby winding the tape onto the take-up spool 2. The take-up spool 2 is driven by the stepper motor 1 so as to rotate through a predetermined number of angular steps, the number of steps being controlled by the controller 12. The amount of tape wound onto the take-up spool 2 is dependent upon the size of each angular step and the diameter of the take-up spool 2 (including tape already wound on the spool). If X steps of ϑ degrees per step are taken, and the take-up spool has a diameter D, the amount of ribbon wound onto the spool is determined by:

$$R = X\vartheta\pi D/360 \qquad (5)$$

The supply spool 3 is driven by the DC motor 4 so as to provide torque in an anti-clockwise direction as viewed in Figure 6. The torque provided by the DC motor 3 determines tension in the tape. The magnitude of the tension is determined by both the torque generated by the DC motor 4 and by the radius of the supply spool 3 as discussed above. Given that the motor 4 is a DC motor, the DC motor current is controlled in accordance with the following equation:

$$C=KTR$$

Where C is the drive current provided to the motor 4, T is the required tension, R is the radius of the supply spool 3, and K is a constant which converts the DC motor current to the torque generated by the DC motor 4.

The output 14 of the calibrator 13 indicates the current radius of the supply spool 3 calculated on the basis of an initial calibration measurement of the diameters of the supply spool 3 and the take-up spool 2 and monitoring of rotation of the stepper motor 1, that rotation when taken in combination with the known diameter of the take-up spool 2 enabling the calculation of the current diameters of both of the spools. Thus all the information required to appropriately control the current supplied to the DC motor 4 is made available to the controller 12 which appropriately adjusts a current demand signal applied to the DC drive 11. The controller 12 also supplies stepper pulses to the stepper motor drive 10 so as to control rotation of the take-up spool 2.

The DC motor-based arrangement of Figure 6 is advantageous when compared with prior art mechanical slipping clutch arrangements as it enables a relatively constant tape tension to be maintained regardless of changes in the diameter of the supply spool 3. A disadvantage however with the embodiment of Figure 6 is that the DC motor and its associated drive controller is expensive. Furthermore, the arrangement of Figure 6 does not lend itself to bi-directional drives which are advantageous in many applications. An alternative embodiment of the

invention which is capable of bi-directional drive is illustrated in Figure 7. The embodiment of Figure 7 corresponds in general terms with the arrangement illustrated in Figure 5 and the same reference numerals are used where appropriate in Figures 5 and 7.

Referring to Figure 7, a non-slip free-running roller 32 which forms part of tape transport measurement device 28 is in contact with the tape between the rollers 5 and 6. Rotation of the roller 32 is detected by a suitable detector which provides the output 29 indicative of tape transport to calibrator 13. The calibrator 13 also receives an output from the motor 4 which in this embodiment is a stepper motor and a further output 33 from the stepper motor 1. (As discussed above with reference to Figure 3, it will be appreciated that as the output 33 is representative of rotation of the stepper motor 1 the required motor rotation information could and in practice generally would be derived from either the motor drive 10 or the controller 12 rather than the motor). The controller 12 provides stepper pulses to the motor drive circuit 11 which in turn generates a drive current that operates the stepper motor 4. The controller 12 also provides an enable signal E1 to the stepper motor drive 11. The second drive circuit 10 also receives stepper pulses and an enable input E2 from the controller 12.

When it is desired to wind the tape onto the spool 2, the controller 12 provides a "high" enable signal E2 to the drive circuit 10 together with pulses which control rotation of the motor 1 that drives the spool 2 in the clockwise direction. The controller 12 provides a "low" enable signal to the stepper drive 11 so that the circuit 11 generates no drive current. Windings of the motor 4 are connected to a programmable load circuit. Since no drive current is provided to the stepper motor 4, the motor resists the drive to which it is subjected by tension in the tape coupled to the supply spool 3. This resistance produces a "drag" torque which tensions the tape. The drag torque is dependent upon the current generated in the motor windings of the motor 4 as it is forced by the tape to rotate. The generated current, and hence the tension, is determined by the characteristics of the load circuit.

It will be appreciated that the arrangement of Figure 7 can be operated in both possible tape transport directions simply by reversing the manner in which the two stepper motors are controlled. Thus if the spool 2 is the take-up spool, the motor 1 is driven whereas the motor 4 provides drag. If the take-up spool is spool 3, the motor 4 is driven and the motor 1 provides drag torque.

The illustration of the roller arrangement of Figure 7 is purely schematic, showing the roller 32 in contact with one side of a straight length of tape. In practice, the tape path would be such that the tape would be deflected around the roller 32 to reduce the risk of tape/roller slippage. For example the roller 32 could be positioned between two idler rollers with the roller 32 deflecting the tape into a space occupied by the roller 32 between the idler rollers.

A load circuit suitable for generating the drag torque discussed above is illustrated in Figure 8. Figure 8 also shows components corresponding to the stepper motor 4, stepper drive 11, controller 12 and calibrator 13. A corresponding load circuit and a corresponding drive circuit (not shown in Figure 8) are connected to the other stepper motor 1 of Figure 7.

Referring to figure 8, the stepper motor 4 is provided with drive current by the stepper drive circuit 11 which is controlled by the control circuit 12. Outputs from the drive current circuit 11 are connected to bases of four transistors 34 to 37. The collector of each transistor is connected to a winding of the stepper motor 4, (the windings being labelled in figure 8 as A, $\overline{A}$, B and $\overline{B}$. An opposite end of each winding is connected to a DC positive supply voltage. The emitter of each transistor 34 to 37 is connected to ground.

To operate the stepper motor, the control circuit 12 provides a high enable signal E1 to the drive current circuit 11 together with a series of pulses. The drive current circuit 11 is provided with sequencing control logic which turns on the transistors 34 to 37 in a predetermined order. As each transistor 34 to 37 is

turned on it draws current through a corresponding motor winding, thereby advancing the stepper motor. The number of steps through which the stepper motor is advanced is determined by the number of pulses generated by the control circuit. The sequencing control logic provided by the drive current circuit 11 may provide half step, full step or microstep control.

The load circuit shown in figure 8 comprises four diodes 38 to 41 each of which has an input connected to the output end of a respective motor winding A, $\overline{A}$, B and $\overline{B}$. Outputs of each of the diodes 38 to 41 are connected together and are connected to a power resistor 42. A transistor 43 is connected between the power resistor 42 and the DC positive supply voltage. The transistor 43 is controlled by an active load drive circuit 44 which provides a pulse width modulated signal to the base of the transistor 43. A logic inverter 45 is connected between the enable output of the control circuit 12 and the active load drive circuit, to ensure that the active load drive circuit 44 is turned on only when the drive current circuit 11 is turned off. The control circuit 12 also provides a pulse width modulated signal which is passed to the active load drive circuit 44.

The base voltage of the active load drive circuit 44 is referenced to the DC positive supply voltage. This means that a level shift circuit 46 is required to raise the level of the enable signal and the pulse width modulated signal passed to the active load drive circuit 44. A separate positive bias voltage on input 47 provides power to the active load drive circuit 44.

The load circuit is used to control the amount of work carried out by the stepper motor 4 when it is forced to rotate by tape being pulled from the supply spool (i.e. when pulled from left to right in figure 7). Each winding of the motor 4 behaves as a generator and generates an AC waveform, as shown by the rectified waveforms in figure 9. Rectification of the generated motor voltage is provided by the diodes 38 to 41. The arrangement of diodes assumes a two phase stepper motor. It will be appreciated that for example a five phase stepper motor could also be used, and where this is the case more diodes would be required. Since the

outputs of all the diodes 38 to 41 are connected, the voltage seen at the power resistor 42 will be the peak of each separate waveform (this is due to the blocking effect of each diode). If the motor is pulled faster or slower then the output voltage generated will be correspondingly increased or decreased.

The active load drive circuit 44 controls the amount of net current that is allowed to flow through the power resistor 42 by adjusting the duty cycle of the pulse wave modulated signal provided to the base of the transistor 43. A high duty cycle will result in a large load current being drawn through the power resistor 42, whereas a low duty cycle will result in a small load current being drawn through the power resistor 42. In order to generate a large load current the stepper motor 4 must work hard, and this is reflected in a high drag torque. A low duty cycle will result in a smaller load current being drawn through the power resistor 42. Less work is required in order to generate the smaller load current, and the drag torque provided by the stepper motor will be correspondingly reduced.

The duty cycle of the pulse wave modulated signal passed to the transistor 43, and hence the load current drawn through the power resistor 42, is controlled by the control circuit 12. When the spool connected to the stepper motor 4 has a large diameter, the duty cycle of the pulse width modulated signal must be high in order to provide a required amount of tension to the ribbon (the tension is proportional to the drag torque and inversely proportional to the radius of the spool). As the radius of the spool decreases (tape having been supplied from the spool) the duty cycle of the pulse width modulated signal is reduced, thereby reducing the torque generated by the stepper motor 4 and maintaining the tension in the tape at a substantially constant level. The control circuit 12 is provided with a signal 14 from the calibration 13 indicating the radius of the supply spool to enable stabilisation of tape tension.

It will be appreciated that the load circuit shown in figure 8 could be implemented for a lower number of motor windings of the stepper motor.

However, this would result in a significant ripple being introduced into the drag torque, since the net current flow through the stepper motor would have a significant ripple content.

The diodes 38 to 41 isolate the load circuit from the drive current circuit 11, since they effectively block current flow from the drive current circuit. In addition, the load circuit transistor 43 is disabled by the active load drive circuit 44 during conventional motor drive.

A disadvantage of the load circuit shown in figure 8 is that the drag torque generated by the stepper motor 4 is dependent upon the speed of rotation of the stepper motor. This will not affect operation of the circuit if the speed of rotation of the take-up spool (2 in figure 7) is unchanging or varies in a known manner, as the load circuit can be calibrated appropriately before operation. However, when the speed of rotation of the take-up reel is variable and cannot be included in a calibration of the active load, the drag torque generated by the stepper motor will include unwanted variation. A circuit which overcomes this disadvantage is shown in figure 10.

The components shown in figure 10, other than the load circuit, correspond to those shown in figure 8 and are not therefore described further. The load circuit itself is substantially modified. The power resistor 42 is connected between the transistor 43 and the DC positive supply voltage. A first filter formed by a resistor 48 and capacitor 49 is connected to the pulse width modulated signal output from the control circuit 12. A second filter formed by a resistor 50 and capacitor 51 is connected across the power resistor 42.

The output of the second filter is connected to the inverting input of an operational amplifier 52, and the output of the first filter is connected to the non-inverting input of the operational amplifier 52.

The output of the operational amplifier 52 is connected to the non-inverting input of a second operational amplifier 53. A sawtooth ramp generator 54 is connected to the inverting input of the operational amplifier 53. The output from the second operational amplifier is connected to the base of the transistor 43.

In use, the first filter filters and averages the pulse width modulated voltage output by the control circuit 12 (and shifted by the level shift circuit 46) to provide a DC voltage. The second filter filters and averages the pulse width modulated current passed by the transistor 43 (i.e. the current generated by the windings of the stepper motor 4) to provide a DC voltage. The first operational amplifier 52 compares the required current as determined by the control circuit 12 with the generated current. The operational amplifier 52 amplifies the difference between the required current and the generated current and passes the amplified difference signal to the second operational amplifier 53.

The second operational amplifier 53 subtracts a sawtooth waveform, having a repeat frequency of 10 to 100 kHz, from the amplified difference signal. The output from the second operational amplifier 53 is a variable pulse width modulated waveform that will adjust the average current generated by the stepper motor 4 to keep it relatively constant and at the level required by the control circuit 12. In this way the drag torque provided by the stepper motor 4 is made independent of the level of electromotive force induced in the stepper motor 4.

The embodiments of the invention described above which rely upon 'conservation of area' as in Figure 4 assume no dimensionally significant changes in the tape as the tape travels from the supply to the take-up spool. This will be the case if the tape is an ink transfer tape but not in other circumstances, for example if the tape carries adhesive labels which are transferred to a substrate. Even with label-carrying tapes however the invention can be applied given an initial measurement of spool diameter and subsequent calculation of spool

diameter changes. For example, an optical system as shown in Figure 3 could be used to make the initial measurement, and changes in spool diameter could be calculated from the predictable tape thickness of the tape as wound on the supply spool before any labels are removed.

CLAIMS

1. A tape drive comprising first and second motors, first and second tape spool supports on which respective first and second spools of tape may be mounted, each spool being driveable by a respective motor, and a controller for controlling the motors such that the tape may be transported from the second spool to the first spool, wherein the first motor is a stepper motor, and the controller is operative to energise the first stepper motor to draw the tape in a tape transport direction on to the first spool and to control the second motor such that the second motor resists rotation of the second spool in the direction of tape transport, means being provided to determine the diameter of the spool supported by the second spool support, and to vary control of the second motor as a function of the determined diameter of the spool supported by the second spool support, the function being such that tension in the tape is maintained within predetermined limits.

2. A tape drive according to claim 1, wherein the diameter determining means comprises means for measuring the diameter of the second spool.

3. A tape drive according to claim 2, wherein the measuring means are optical.

4. A tape drive according to claim 3, wherein the measuring means comprises at least one optical emitter positioned such that a shadow is cast by at least the second spool, at least one optical detector adapted to detect the position of an edge of the shadow, and means to determine the diameter of the second spool from the detected position of the edge of the shadow.

5. A tape drive according to claim 4, wherein at least one emitter or detector is mounted on a translatable carriage, such that components of the optical measuring means are displaced through a position corresponding to the said shadow edge.

6. A tape drive according to claim 5, wherein a said detector is mounted on the translatable carriage and two emitters are positioned such that the first and second spools cast shadows edges of which are located on a track along which the detector is displaced.

7. A tape drive according to claim 5, wherein a said emitter is mounted on the translatable carriage and two detectors are positioned such that the edges of shadows cast by the first and second spools are displaced past the detectors as the emitter is displaced on the carriage.

8. A tape drive according to claim 5, wherein a said emitter and a said detector are mounted on the carriage, and a mirror is positioned to reflect light from the emitter to the detector, at least the second spool being located between the carriage and mirror such that the second spool obstructs reflection of light from the emitter to the detector to an extent dependent upon the diameter of the second spool.

9. A tape drive according to claim 4, wherein the at least one detector comprises an elongate array of detectors positioned such that the said shadow edge moves along the length of the array as the diameter of the second spool changes.

10. A tape drive according to any one of claims 2 to 9, wherein the tape drive is part of a printer which operates cyclically with each cycle including a printing operation, and the diameter of the second spool is measured between successive printing cycles.

11. A tape drive according to claim 1, wherein the diameter determining means comprises means for calculating the diameter of the second spool.

12. A tape drive according to claim 11, comprising means for monitoring tape transport, means for monitoring rotation of at least one motor, and means for calculating the diameter of the second spool from the measured tape transport and motor rotation.

13. A tape drive according to any preceding claim, comprising means for estimating the current diameter of the second spool from a previously determined spool diameter and subsequent operation of the tape drive.

14. A tape drive according to claim 13, wherein the estimating means is operative to estimate the current diameter on the assumption that the total cross-sectional area of the supply and take-up spools is a constant.

15. A tape drive according to any preceding claim, wherein the first and second motor are stepper motors, the second motor is connected to a load, and means are provided to control current drawn by the load as a function of the determined diameter.

16. A tape drive according to claim 15, comprising a feedback circuit connected to the load, the feedback circuit being configured to maintain the current drawn by the load at a required level determined by the controller.

17. A tape drive according to claim 15 or 16, wherein the current control means comprises connection means which periodically connects the load to the windings of the second stepper motor in accordance with a pulse width modulated signal, adjustment of the pulse width modulated signal providing adjustment of the average load current.

18. A tape drive according to claim 17 as dependent upon claim 16, wherein the feedback circuit comprises a first filter which provides a DC value indicative of the current passing through the load, a second filter which provides a DC

value indicative of the pulse width modulated signal, and means for comparing the DC values to provide a feedback signal.

19. A tape drive according to claim 18, wherein the feedback circuit further comprises a sawtooth function generator arranged to generate a sawtooth signal, and means for comparing the feedback signal and the sawtooth signal to provide a sawtooth modulated feedback signal which controls the connection means.

20. A tape drive according to claim 17, 18 or 19, wherein the connection means is a transistor which is turned on and off by the pulse width modulated signal.

21. A tape drive according to any one of claims 15 to 20, wherein diodes are connected between windings of the second stepper motor and the load to prevent flow of current from the load to the windings.

22. A tape drive according to any one of claims 15 to 21, wherein the controller is provided with enable means configured to ensure that current is passed from the windings of the second stepper motor to the load only when drive current is not being supplied to the second stepper motor.

23. A tape drive according to any one of claims 15 to 22, wherein each element of the tape drive which is provided for the second stepper motor is in addition provided for the first stepper motor and vice versa, such that tape may be transported from the first reel to the second reel.

24. A tape drive according to any one of claims 1 to 14, wherein the second motor is a DC motor, and means are provided to control drive current to the DC motor as a function of the determined diameter.

25. A tape drive according to claim 24, wherein the drive current is directly proportional to the determined diameter.

26. A tape drive according to any preceding claim, wherein the tape is an ink-carrying tape for use in a transfer printer.

27. A tape drive according to any one of claims 1 to 25, wherein the tape is a label-carrying tape for use in a label applicator.

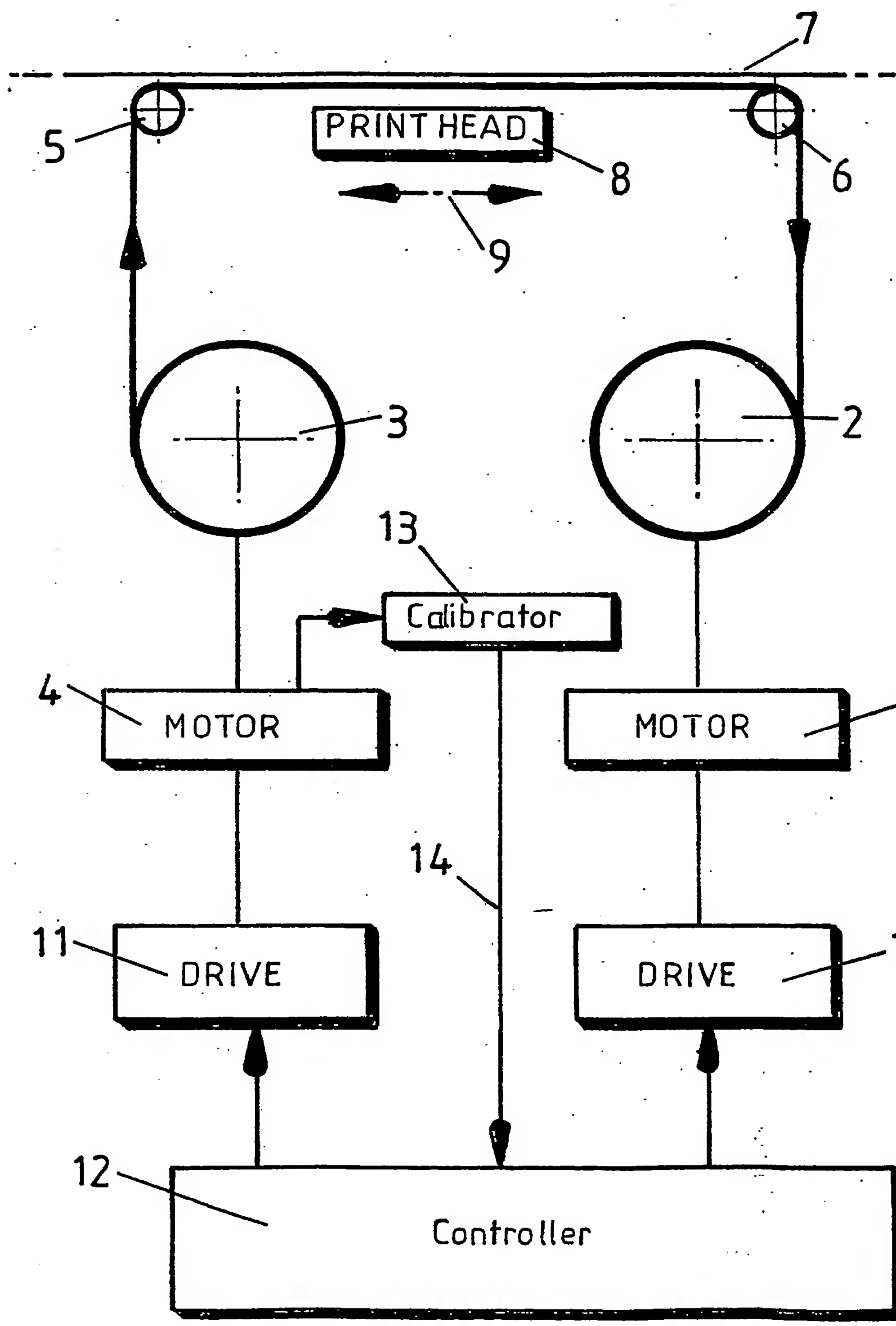

7
PRINT HEAD
5
8
6
9
3
2
13
Calibrator
4
MOTOR
MOTOR
1
14
11
DRIVE
DRIVE
10
12
Controller

FIG.1

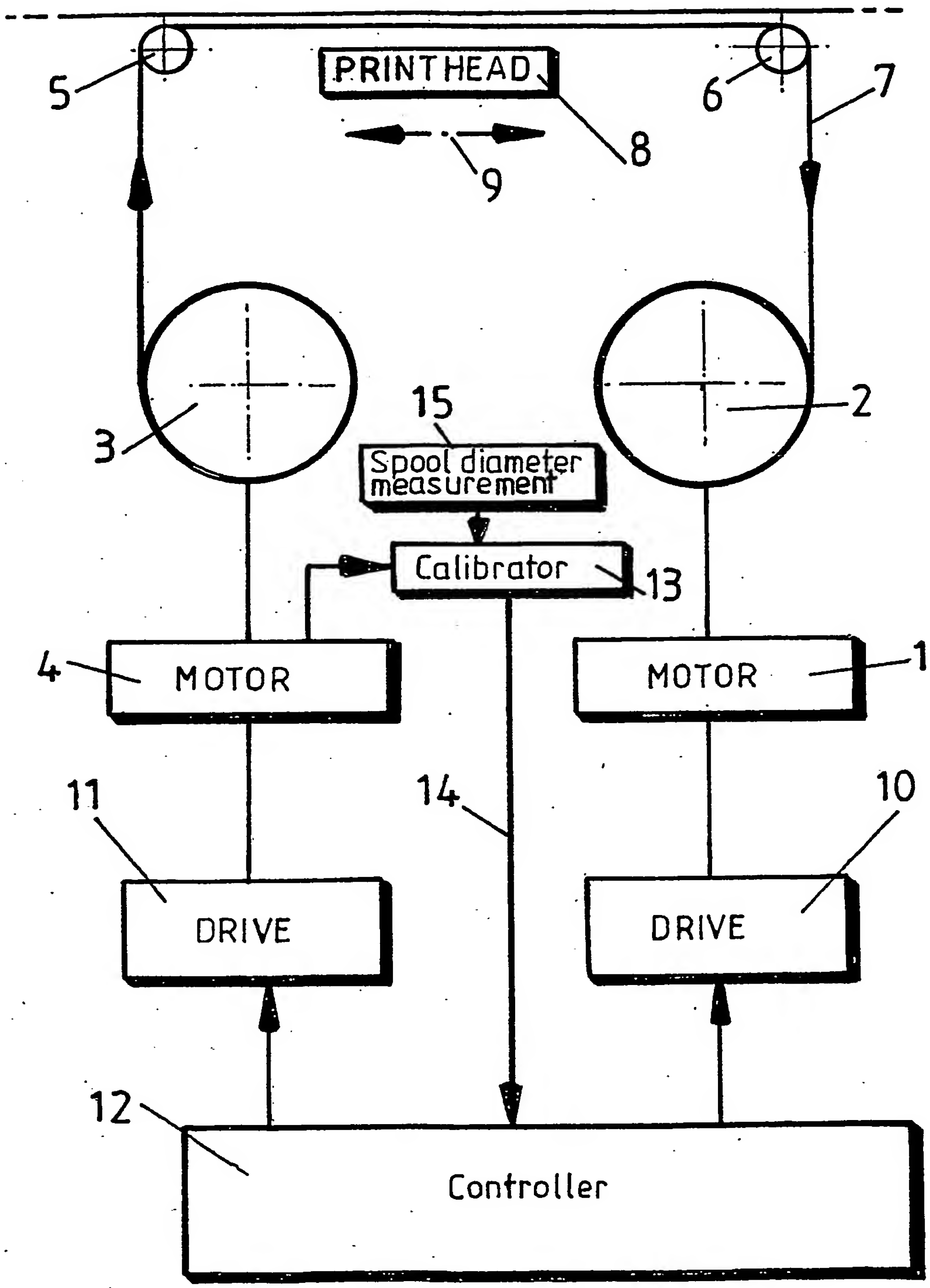

PRINTHEAD
5
6
7
8
9
3
2
15
Spool diameter measurement
Calibrator
13
4
MOTOR
MOTOR
1
11
14
10
DRIVE
DRIVE
12
Controller

FIG.2

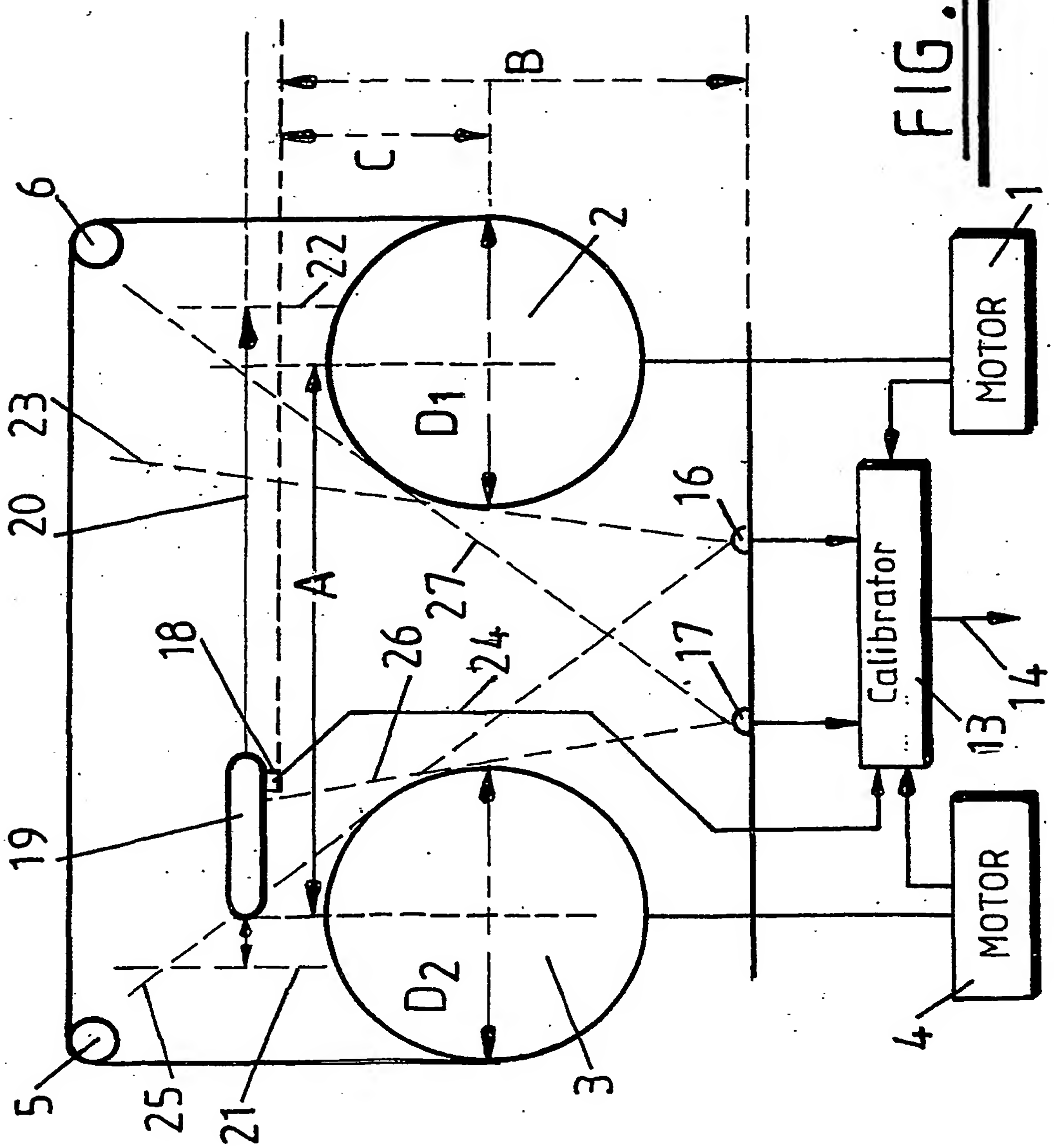

MOTOR
MOTOR
Calibrator
A
B
C
D1
D2
1
2
3
4
5
6
13
14
16
17
18
19
20
21
22
23
24
25
26
27

FIG. 3

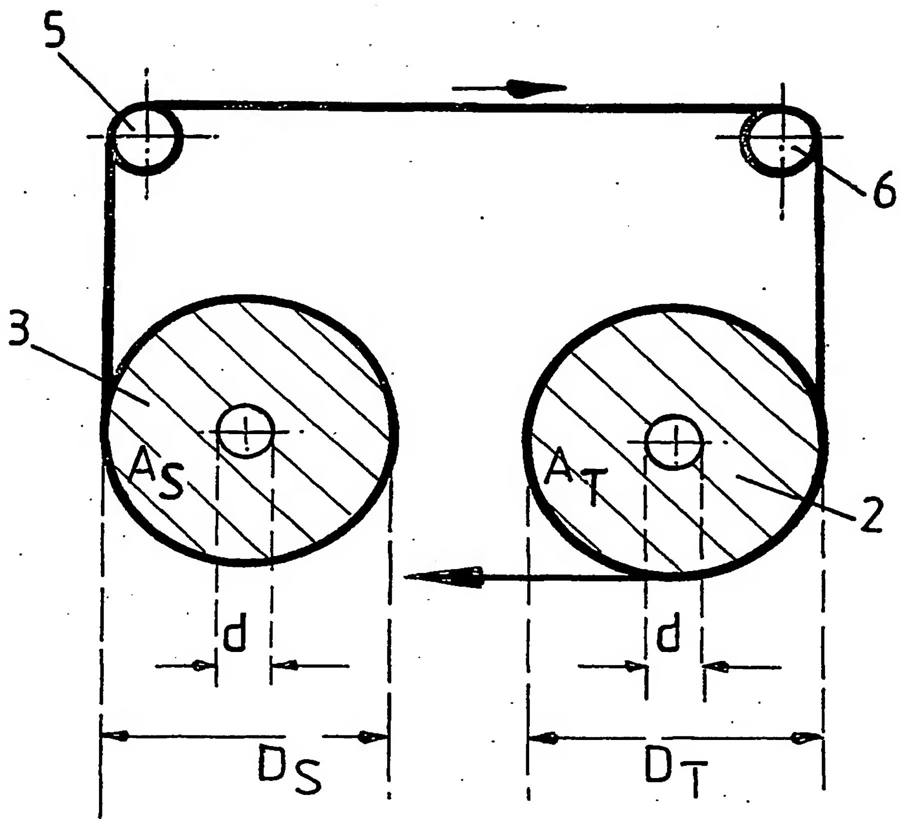


FIG.4

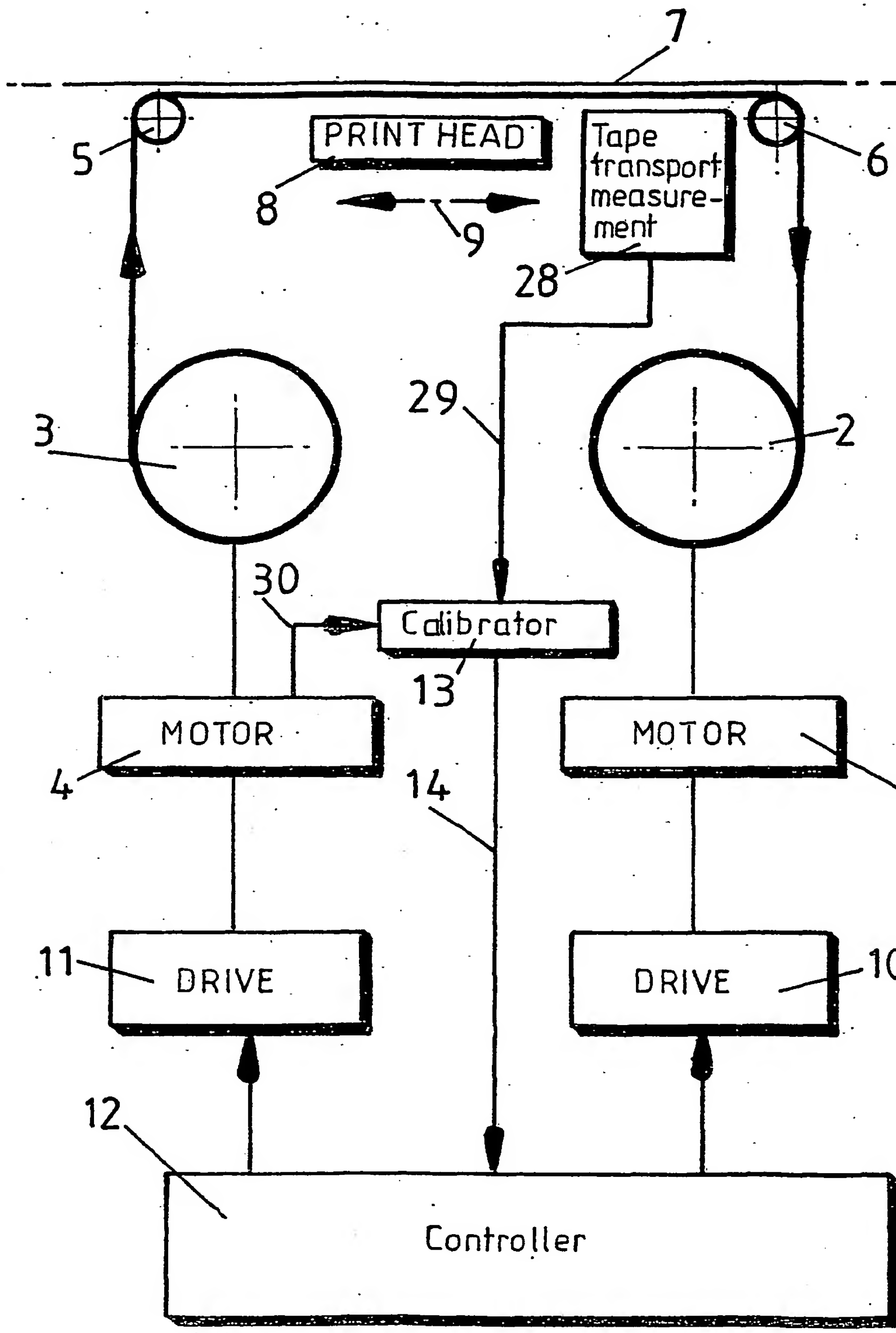

7
PRINT HEAD
Tape transport measure-ment
5
6
8
9
28
29
3
2
30
Calibrator
13
MOTOR
MOTOR
4
1
14
11
DRIVE
DRIVE
10
12
Controller

FIG. 5

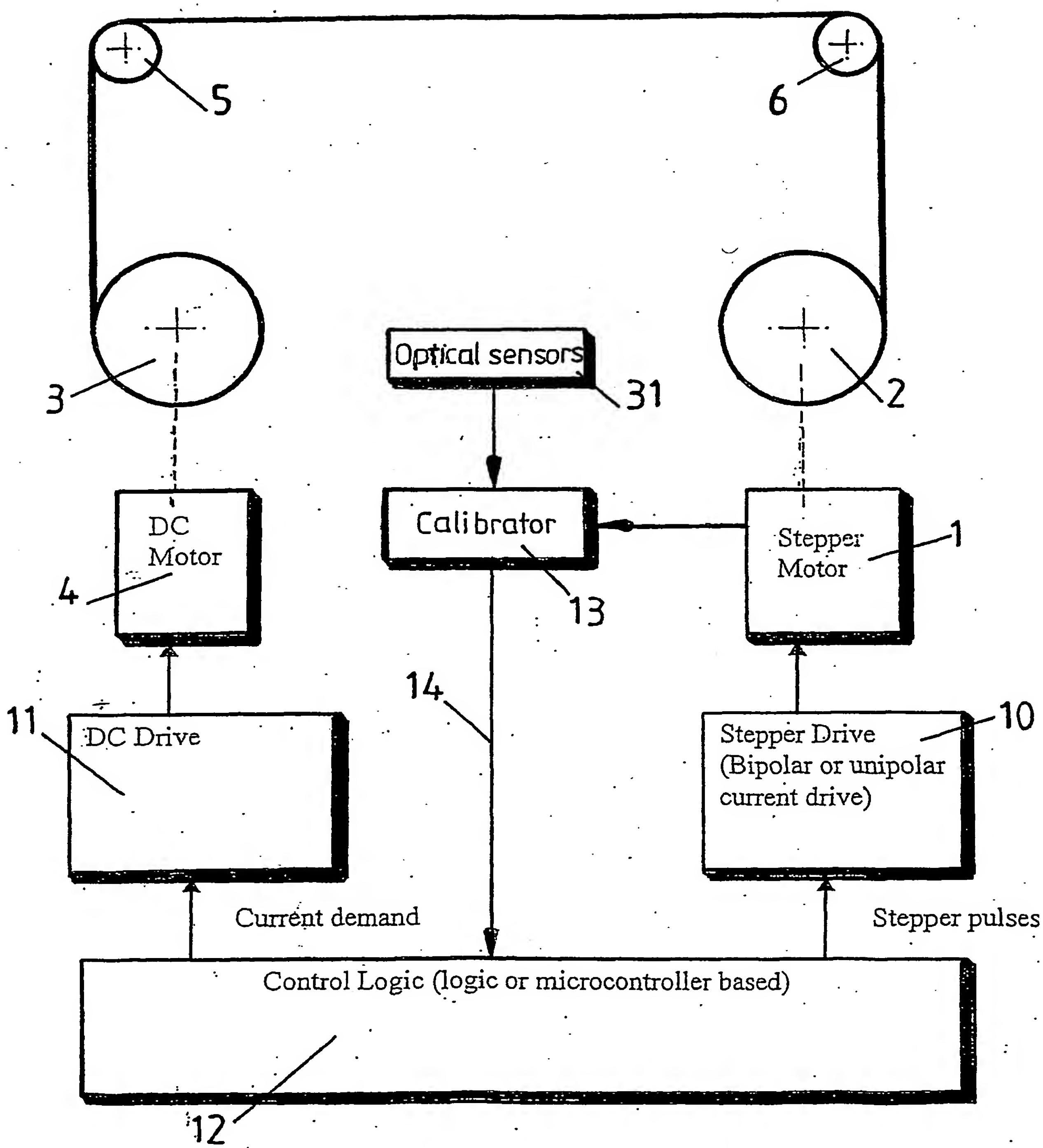

5
6
3
2
Optical sensors
31
DC Motor
4
Calibrator
13
Stepper Motor
1
14
11
DC Drive
Stepper Drive (Bipolar or unipolar current drive)
10
Current demand
Stepper pulses
Control Logic (logic or microcontroller based)
12

FIG. 6

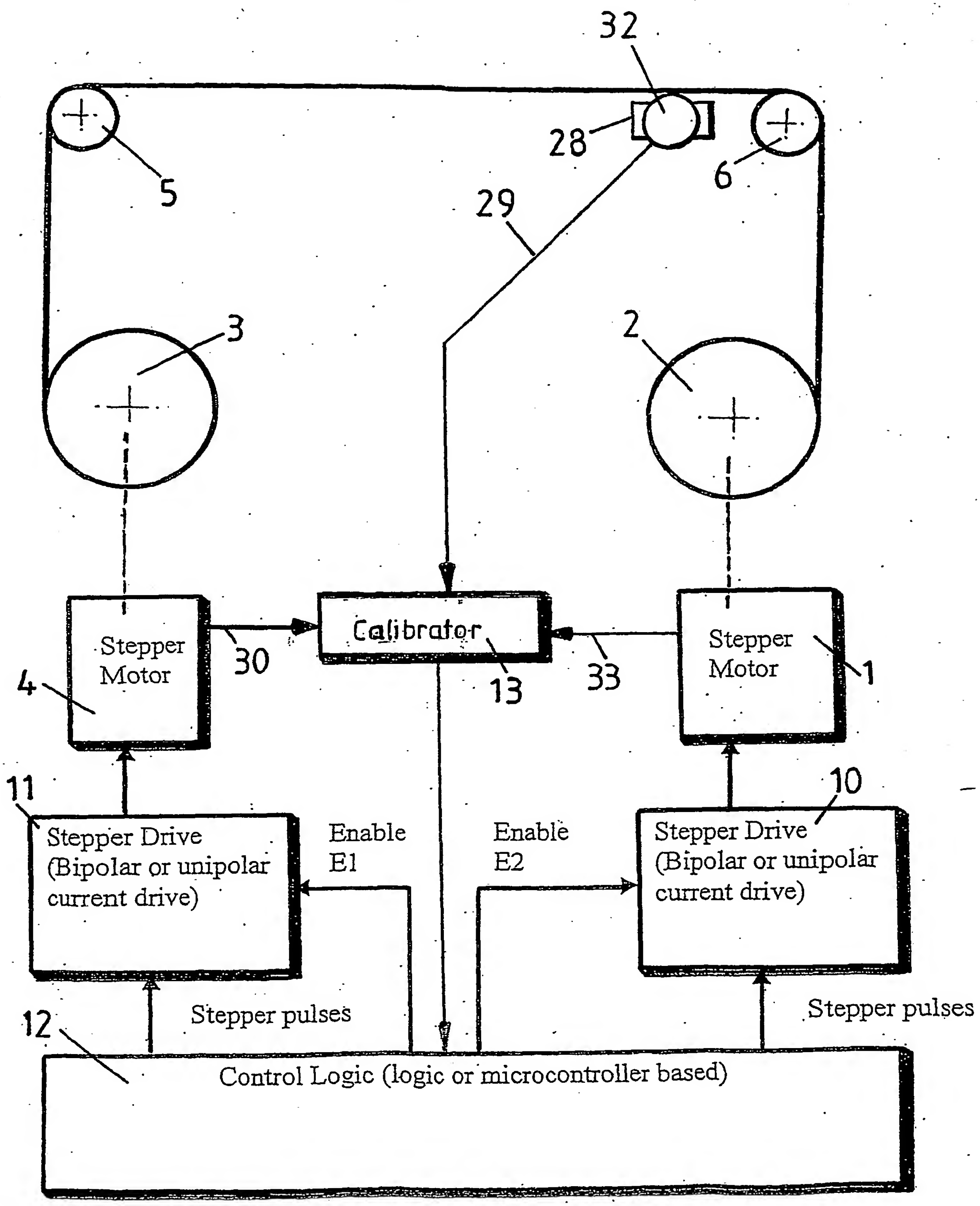
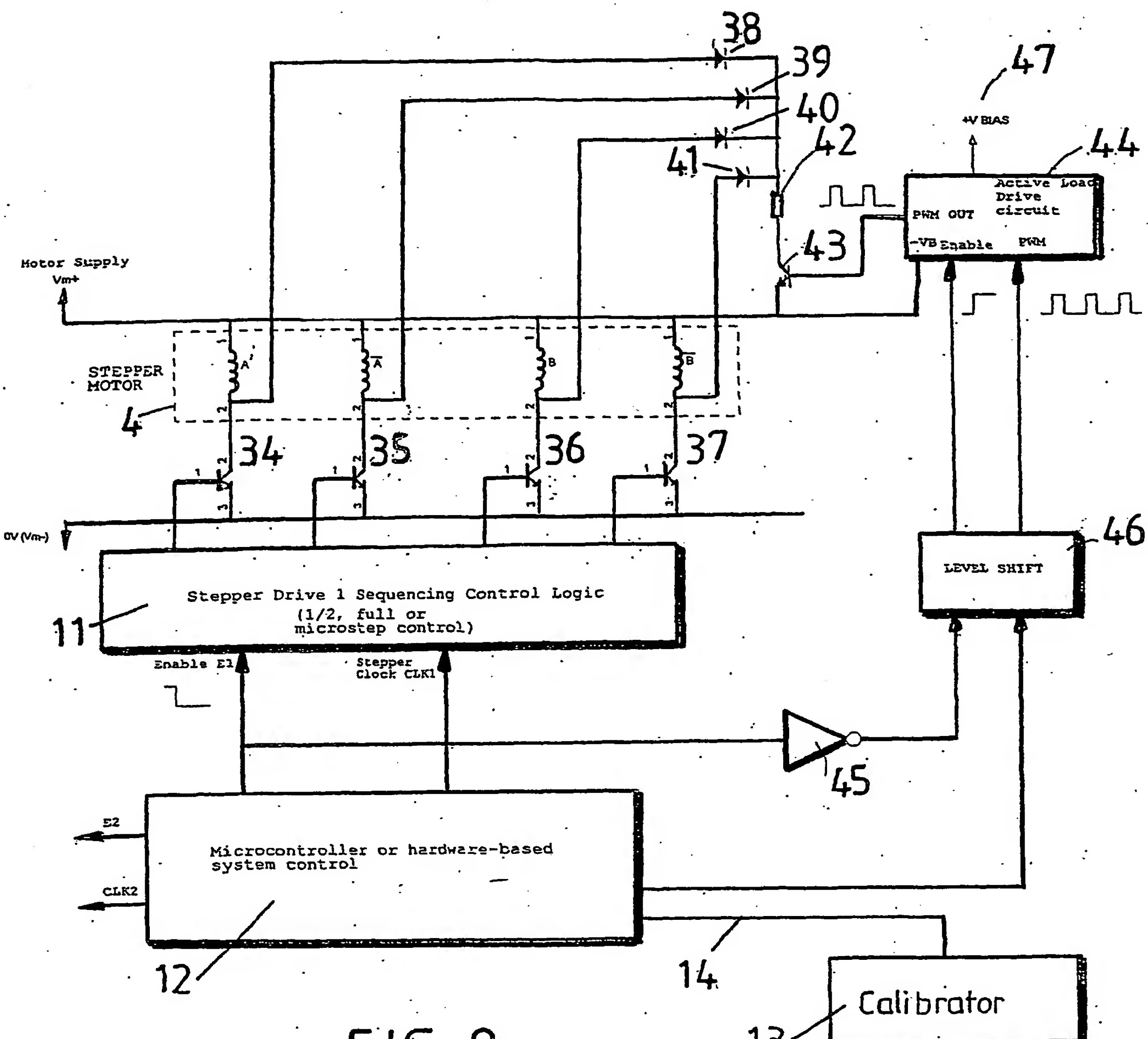
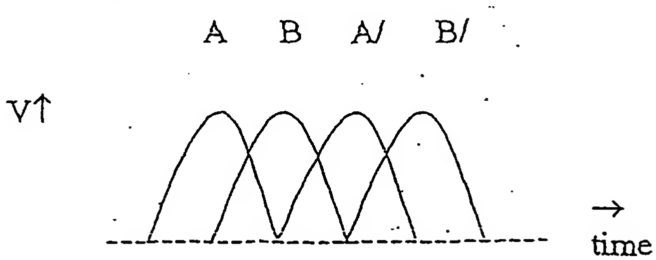

32
28
6
5
29
3
2
Calibrator
Stepper Motor
Stepper Motor
4
30
13
33
1
11
10
Stepper Drive (Bipolar or unipolar current drive)
Enable E1
Enable E2
Stepper Drive (Bipolar or unipolar current drive)
12
Stepper pulses
Stepper pulses
Control Logic (logic or microcontroller based)

FIG.7



38
39
40
41
42
43
47
+V BIAS
44
Active Load Drive circuit
PWM OUT
-VB Enable
PWM
Motor Supply Vm+
STEPPER MOTOR
4
34
35
36
37
0V (Vm-)
46
LEVEL SHIFT
Stepper Drive 1 Sequencing Control Logic
(1/2, full or microstep control)
11
Enable E1
Stepper Clock CLK1
45
E2
CLK2
Microcontroller or hardware-based system control
12
14
Calibrator
13

FIG. 8



A B A/ B/
V↑
→ time

FIG. 9

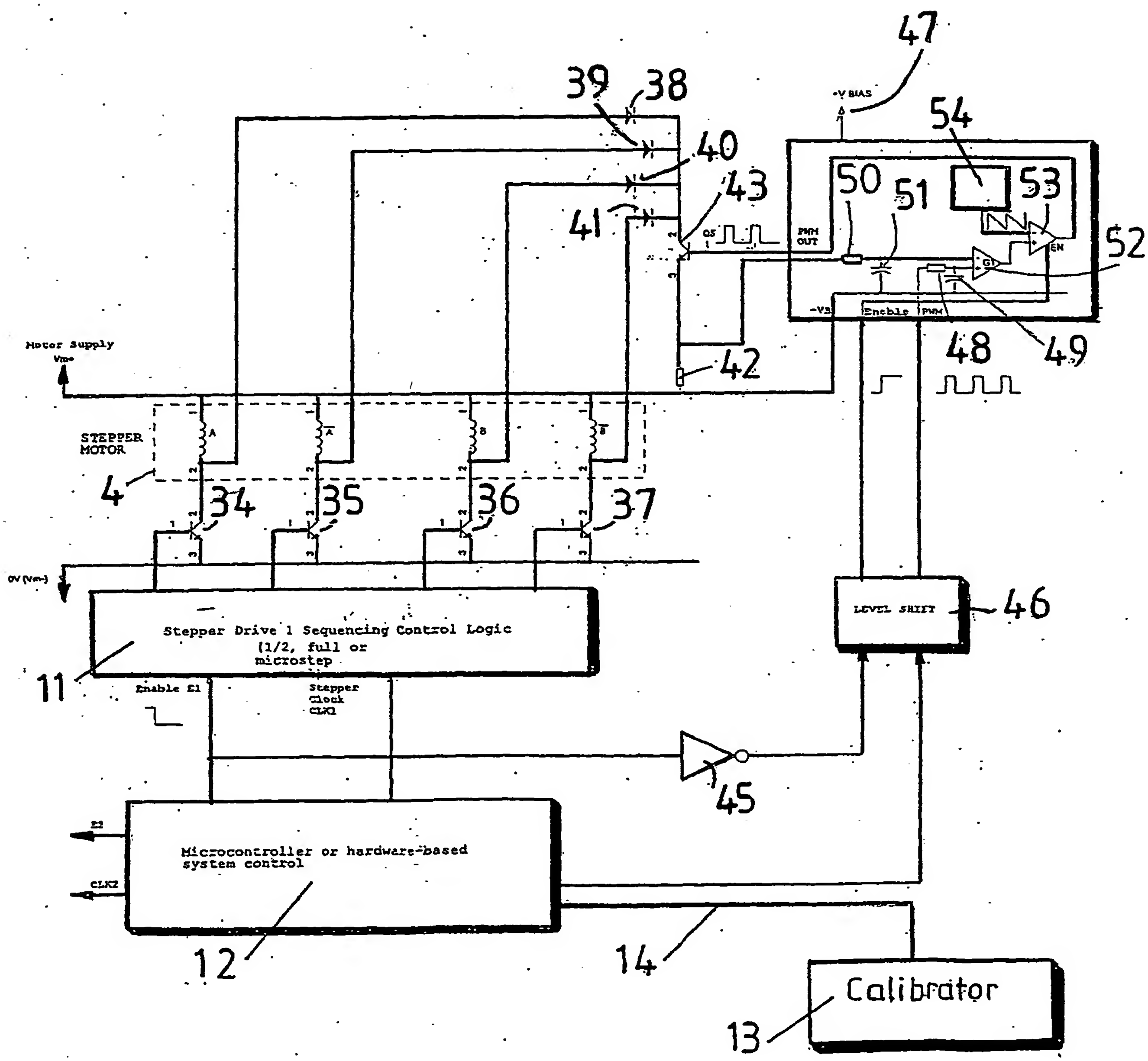

47
+V BIAS
39
38
40
43
41
54
50
51
53
52
PWM OUT
-VS
Enable
PWM
48
49
42
Motor Supply
STEPPER MOTOR
4
34
35
36
37
0V (Vm-)
Stepper Drive 1 Sequencing Control Logic (1/2, full or microstep
11
Enable E1
Stepper Clock CLK1
LEVEL SHIFT
46
45
Microcontroller or hardware-based system control
E2
CLK2
12
14
Calibrator
13

FIG.10

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 02/04405

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B41J33/34 G11B15/43

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B41J G11B B65H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, INSPEC, IBM-TDB, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 294 552 A (MAKO JOHN) 13 October 1981 (1981-10-13) cited in the application	1,2,11, 15,24,26
A	column 2, line 18 - line 41	13
Y	PATENT ABSTRACTS OF JAPAN vol. 1996, no. 05, 31 May 1996 (1996-05-31) & JP 08 002078 A (TEC CORP), 9 January 1996 (1996-01-09)	1,2,11, 15,24,26
A	abstract	13
A	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 11, 30 September 1998 (1998-09-30) & JP 10 162452 A (SANYO ELECTRIC CO LTD), 19 June 1998 (1998-06-19) abstract	1,2

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 February 2003	20/02/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	De Groot, R

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 02/04405

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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